FOREST PEST MANAGEMENT
Pacific Southwest Region

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Evaluation of Insect and Disease Conditions in the Ice Project Area, Greenhorn Ranger District, Sequoia National Forest

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BACKGROUND

In response to a request from the Greenhorn District, Sequoia National Forest, John Wenz, Entomologist, and John Pronos, Plant Pathologist, Forest Pest Management (FPM) South Sierra Shared Service Area, conducted an evaluation on July 6-7, 1993, of the Ice Project area (T25&26S, R32E). The Ice Project was developed in response to fire hazard concerns expressed by local homeowners in the Alta Sierra tract in the Greenhorn Mountains. The basic objective of the Project is "to improve the health and vigor of the forest in the analysis area to meet multiple resource needs" with an emphasis on reducing fuel loading and fire hazard. The area has experienced above normal levels of mortality during the past 3-4 years as a consequence of drought, bark beetle, disease and stand condition interactions. The objectives of the evaluation were to (1) identify the important insects and diseases active in the project area, and (2) discuss pest management options available to the District for consideration in developing the Environmental Assessment for the project.

OBSERVATIONS

The project area covers approximately 6,000 acres of which about 4,250 acres are CAS mixed conifer stands, 1,149 acres are mixed chaparral and foothill woodland vegetation and 601 acres are private land. In addition, there are about 130 acres of plantations that range from 5 to 28 years in age. The mixed conifer stands consist of ponderosa, sugar and Jeffrey pine, white fir, incense-cedar and black oak and range from pole-sized to old-growth size classes. Stocking densities range from about 130 to 330 sq.ft./acre with an area-wide average of 250 sq.ft./acre. Dense stands of small diameter (<12 inches DBH) regeneration, primarily incense-cedar and white fir, occur throughout the project area.

The evaluation was conducted primarily along roads 25S16 (Black Mountain Saddle), 25S17 (Greenhorn Summit), and 25S21 (Shirley-Cooks Peaks). The following insect and disease-related observations are characteristic of the project area in general.

Insects

Abnormally high levels of bark and engraver beetle-related mortality, both past and present, were evident throughout the project area. Current mountain pine beetle (MPB), Dendroctonus ponderosae (Coleoptera: Scolytidae) activity in sugar pine was noted throughout the project area and in adjacent drainages. (The biologies of all pests discussed in this report are included in the Appendix.) Adult MPB had initiated gallery construction and started egg laying. The foliage on currently infested sugar pines varied from green (no fade) to slightly off-color yellowish-brown, usually more pronounced from the top down. These MPB infested trees may also be infested with pine engravers, Ips sp., in the upper third of the crown. Some Jeffrey pine appeared off-color near Cooks Peak. Examination of the lower bole of some of these trees did not reveal evidence of Jeffrey pine beetle (JPB), D. jeffreyi, or engraver beetle attack but they may have been attacked in the mid to upper bole above the area examined.

No currently infested ponderosa pine were observed within the project area. However, 5 ponderosa pine currently under attack by the western pine beetle (WPB), D. brevicomis, were examined in the vicinity of Davis Creek, south of the project area. Three of the trees had adult WPB in the process of boring in through the bark while two of the trees had adult gallery development and initiation of egg laying in niches along the sides of the galleries. As with the MPB-infested sugar pine, foliage color varied from green to light straw, fading from the top down. The red turpentine beetle (RTB), D. valens, was found attacking the base of 3 of the WPB infested pines. Considerable past and current mortality, top-kill and branch dieback to white fir was evident throughout the project area affecting both overstory and intermediate sized trees. Such damage is characteristic of fir engraver, Scolytus ventralis, activity.

In addition, larval mining was found in the bole and limbs of white pine blister rust infected sugar pine regeneration near a plantation along 25S17. The boring was evidenced by resin-soaked, reddish colored, masses of coarse boring dust on the bark in the immediate vicinity of blister rust limb and branch cankers. The mined galleries were short (<5 cm), heavily resinous and sometimes "C"-shaped. One unidentified lepidopterous larva and one pupa were found in the galleries. This injury may be attributable to boring/feeding by the sequoia pitch moth, Synanthedon (Vespamima) sequoiae (Lepidoptera: Sesiidae). The sequoia pitch moth attacks several pines, including sugar pine (but has not been recorded attacking sequoia despite it's name), and generally causes a much larger pitch mass than seen on this rust infected sugar pine regeneration. Attacks are often associated with injuries, in this case, blister rust cankers. Repeated, high density attacks, may severely affect and weaken individual trees, but impacts on stands have generally been considered of minor importance.

Diseases

Western dwarf mistletoe (Arceuthobium campylopodum), which infects ponderosa and Jeffrey pines, was restricted to a few locations within the project area. In general, the intensity of infection was moderate, but in some cases dwarf mistletoe was severe enough (Hawksworth ratings of 5 and 6) to contribute to successful attacks by the western pine beetle. The greatest concentration and most severe infection was present along Road 25S21 just east of Cook's Peak.

White pine blister rust, caused by Cronartium ribicola, was found primarily along Road 25S17 on seedling, sapling and pole-size sugar pines. Most cankers and dead branches were fairly old with very little current aecial sporulation. Although some sugar pines up to 8 inches DBH were still being killed, the majority of infections dated back to the early or mid 1980's. The worst damage from blister rust was found in a 20-25 year old plantation where sugar pine accounted for up to 50% of the planting stock. Ribes was abundant in many sites and already producing uredia.

Viable conks of the fungus, Heterobasidion annosum, were found in white fir stumps at two locations. One site was in an old clearcut about 2 miles south of Greenhorn Summit along Road 25S17, and the other was near where the southern portion of Road 25S17 intersects Rancheria Road. This pathogen causes annosus root disease; it appeared restricted to white fir and was not causing obvious tree mortality. The incidence of annosus root disease generally increases proportionally with the amount of cutting that has occurred in a stand. Areas within the Ice Project that have not been repeatedly cut, probably have little root disease.

True mistletoe (Phoradendron bolleanum subsp. paciflorum) was prominent in white fir in stands north of Black Mountain Saddle. It was common to see dense mistletoe plants in the tops and upper crowns of overstory fir. We did not observe any tree mortality associated with true mistletoe, but heavy infestations in the tops of white fir often lead to top kill from fir engraver beetle attacks.

MANAGEMENT ALTERNATIVES

Following is a discussion of pest management alternatives, including the no action alternative, for consideration in the development of the Ice Project Environmental Analysis. The anticipated effect of each alternative on insect and pathogen activity, plus the subsequent impact on vegetation, is described.

1. No Action. In the Ice Project Area, above-normal levels of bark and engraver beetle-related mortality experienced over the past few years are primarily due to (1) extended drought conditions, (2) overstocking, and (3) diseases. These factors combine to weaken the conifers to the extent that they are increasingly susceptible to successful attack by bark beetles. A continued return to normal precipitation should, over the next 1 to 3 years, help reduce the high levels of mortality induced by drought stress. However, even without moisture stress, mortality will fluctuate to some extent from year-to-year and through time, can be expected to be higher in stands with conditions that predispose trees to bark and engraver beetle attack than in stands managed to minimize such conditions.

Mortality and top-kill can result in increased fuel loading, reduced stocking levels, un-regulated openings, increased numbers of snags and downed woody material, and generally reduced tree/stand growth and vigor. The impact or importance of these effects, positive or negative, depends upon the resource management objectives for the stands.

Diseases, which include dwarf and true mistletoes, annosus root disease, and white pine blister rust, will continue to affect stands already infested and will spread to healthy trees. Dwarf mistletoe, in particular, will gradually intensify without management. This pest spreads most rapidly in multi-storied stands if it is established in the overstory. Diseased trees tend to be more susceptible to bark beetle attack.

2. <u>Thinning/vegetation management.</u> Activities designed to thin stands, increase tree vigor and improve forest health offer excellent opportunities to reduce current and future negative impacts of insects and pathogens active in the Ice Project area. Trees with dwarf mistletoe ratings of 5 or 6 should be removed during thinnings since they normally do not live more than 10-15 years and produce many seeds that infect adjacent pines. Sugar pines with lethal blister rust cankers have short life expectancies and are best removed during stand improvement activities. Management of fresh pine slash that results from stand management activities should be considered to minimize/prevent pine engraver problems.

3. <u>Re-vegetation.</u> Any planting should be done giving consideration to the pests present and their potential to damage seedlings or regeneration. Known blister rust resistant sugar pine should be used throughout the project area because rust is already well established. Ponderosa and Jeffrey pines should not be planted under an overstory infested with western dwarf mistletoe. Any pine species, however, could be planted in, and adjacent to, existing annosus centers because only true fir are effected by the type of root disease active within the project boundaries.

4. <u>Protect Rust Resistant Sugar Pine.</u> Because rust resistant planting stock is so essential to maintaining a viable population of sugar pine, known resistant parent trees should be protected. Much time, effort, and money has gone into identifying and screening candidate trees. In the Sierra Nevada, the chief threat to sugar pine health is the mountain pine beetle, particularly during drought years. Mountain pine beetle-related sugar pine mortality is currently very high in and around the project area (as well as other areas in California) and the District should consider whether any of the steps below are justified:

a. THINNING to reduce inter-tree competition, without injuring the residual trees or opening up the stand so much that windthrow might be a problem. Removing brush, particularly <u>Ribes</u> sp., at the same time may be of benefit.

b. **WATERING** trees in the spring after below-normal winter precipitation. Procedures and systems for accomplishing this have been evaluated on other National Forests.

c. **FERTILIZING** low vigor sugar pines or those growing on poor sites may increase or accelerate cone production.

d. **INSECTICIDE SPRAYING** with Carbaryl to protect uninfested sugar pine from bark beetle attack. Ground applications will normally cover the lower 30-40 feet of the bole and be effective for at least one year.

5. Integrate Management Actions. The above options are not independent of each other and can be appropriately incorporated into the overall management of the vegetation at any spatial scale. Combinations of these alternatives may be selected and implemented, depending on the objectives for specific area(s) under consideration.

APPENDIX - PEST BIOLOGIES

Mountain Pine Beetle

The mountain pine beetle, Dendroctonus ponderosae, attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 4 inches dbh. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is the general rule, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine.

Attacks may extend from the root collar up to near the top. Pheromones released during a successful attack may attract enough beetles to result in a group kill. Pitch tubes and red boring dust in bark crevices or on the ground indicate successful attacks.

The adults bore long vertical egg galleries and lay eggs in niches along the sides of the gallery. A "J"-hook is common at the lower end of the gallery. The hatching larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

The sapwood of successfully attacked trees soon becomes heavily bluestained. The bluestain fungi probably aid in overcoming the defenses of the host tree.

Natural factors affecting the abundance of the mountain pine beetle include low winter temperatures, nematodes, woodpeckers and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases snd mortality increases. Relieving stress by thinning dense stands can prevent some group kills. Individual high value trees undergoing temporary reversible stress may be protected from attack by application of insecticide to the bole.

Pine Engraver Beetles

Pine engraver, Ips spp., attacks have been recorded on most species of pines in California. These beetles kill saplings, poles and sawtimber up to about 26 inches dbh and the tops of even larger trees. Attacks on live trees are usually limited to trees which are suppressed, or stressed by dwarf mistletoe, root disease, drought, fire or the attack of other insects. If fresh slash is available in the spring, pine engravers may build up in an area and cause localized mortality or top killing by mid-summer.

Attacks are made with the coming of warm weather in the spring. Attacking males bore nuptial chambers in the inner bark and release a pheromone which

attracts other beetles to the attack site. If many beetles are attracted, they may attack nearby trees and cause a group kill. Within a day or two of the attack by the male, two to five females enter the nuptial chamber and after mating, each female bores an individual egg gallery which lightly scores the sapwood. The size and pattern of the combined gallery pattern is often diagnostic of the species of Ips involved. The galleries are kept open by beetles pushing boring dust out through the entrance hole. Red boring dust collecting in bark crevices or spider webs is diagnostic of a successful attack. Eggs are laid in niches along the sides of the galleries. Larvae hatch from the eggs and feed in the phloem. They eventually pupate in cells at the end of their larval mines and transform to adults.

A new generation is produced in as little as 6-8 weeks in the spring to 4-6 weeks in mid-summer (August). Thus, several overlapping generations per year may be produced. The winter may be passed in any of the life stages of larvae, pupae, or adults, depending upon which Ips species is involved.

Outbreaks in standing, healthy trees are sporadic and of short duration, and are often associated with some temporary stress or shock afflicting the host species, such as drought or logging disturbance. Tree killing frequently occurs where green pine slash, which serves as breeding habitat is left untreated during spring and summer. To be suitable as pine engraver breeding habitat, pine slash must have bark from 1/8 to 1 inch thick (usually 3 to 26 inches diameter), must have succulent cambium and must remain moderately cool during the development period.

Fresh pine slash caused by thinning, dwarf mistletoe control work, construction or winter storm breakage can be modified in a number of ways to make it unsuitable for pine engraver breeding. One approach to minimizing damage is to schedule slash-generating activities mostly between mid-July and late-December, when the slash has a high probability of drying out, heating up, or spoiling before the beetles can complete their development. Utilization of the cut material to the smallest possible diameter will minimize the amount of breeding material available to engraver beetles. If green pine slash must be created during the sring and early summer, slash treatments are available to prevent the buildup of pine engraver populations. Because pine engravers can complete their development in about a month under ideal conditions, treatment should be carried out soon after cutting to be effective.

Slash treatment methods which generally work well include chipping, lopping and scattering slash in sunny areas to heat it up, crushing or mashing slash with logging equipment to make it unsuitable for pine engraver breeding, or piling and burning the slash within a month of cutting. Broadcast burning the slash might work if it could be done without damaging the residual stand. A method which has worked during the summer in hot climates is to pile slash in a sunny area and tightly cover the pile with clear plastic. If the temperature under the bark of slash in all parts of the pile reaches 120^{o}F, all brood currently in the pile will be killed. Lower temperatures will not be effective and, where successful, this method will not prevent reinfestation of slash piles. Because most pine engraver attacks occur within a quarter-mile from the location where the beetles emerged, high value pines can be given some protection by removing fresh pine slash to areas which do not have pines.

Two practices which should generally be avoided are piling fresh pine slash without further treatment, and allowing slash to touch or remain near valuable leave trees.

Jeffrey Pine Beetle

The Jeffrey pine beetle, Dendroctonus jeffreyi, is the principle bark beetle found attacking Jeffrey pine, Pinus jeffreyi, which is its only host. It is a native insect occurring from southwestern Oregon southward through California and western Nevada to northern Mexico. The beetle normally breeds in slow-growing, stressed trees. The beetles prefer trees which are large, mature, and occur singly rather than in groups. Yet when an epidemic occurs, the beetle may attack and kill trees greater than 8 inches in diameter, regardless of age or vigor. Often the beetle infests lightning-struck or wind-thrown trees, but does not breed in slash.

Presence of the beetle is usually detected when the foliage changes color. The color change of the foliage is related to the destruction of the cambium layer by the beetle. Generally, the top of the crown begins to fade in a slow sequence, with the needles turning from greenish yellow, to sorrel, and finally to reddish brown. By the time the tree is reddish brown, the beetles have usually abandoned the tree. Another sign of beetle attack is large, reddish pitch tubes projecting from the bark of the infested tree.

Jeffrey pine beetles have a distinctive "J" shape egg gallery pattern on the inner bark. Larval mines extend across the grain and end in open, oval-shaped pupal cells. The beetle has a 4 life stages, egg, larva, pupa, and adult. The adults are stout, cylindrical, black, and approximatley five-sixteenths of an inch long when mature. The egg is oval and pearly-white. The larva is white, legless, and has a yellow head. The pupa is also white but is slightly smaller than the mature larva. The life cycle is normally completed in one year in the northern part of the range, but in the southern part, two generations per year may occur. The principle period of attack is in June and July, but attacks also are frequent in late September and early October.

Several other organisms are associated with the attack of the Jeffrey pine beetle. Bluestain fungi, yeasts, and other fungi are transferred into the tree by the attacking adults. The California flatheaded borer, Melanophila californica, the pine engraver, Ips pini, and the emarginate ips, I. emarginatus, may precede the Jeffrey pine beetle or attack the tree at the same time.

Natural enemies, climatic factors, and the tree's own resistance, normally keep the Jeffrey pine beetle population in check. Losses in stands can be kept to a minimum by removing the types of trees the beetle prefers, ie. sick, stressed, wounded. The remaining trees may be protected through a sanitation-salvage cutting, preferably before the beetle can emerge from the tree. Other options may be to fell the tree and burn it, peel the bark off or spray the tree. If the beetle has reached the pupal stage, peeling the bark to expose the insect will be ineffective.

Western Pine Beetle

The western pine beetle, Dendroctonus brevicomis, breeds in the main bole of living ponderosa and Coulter pine larger than about 4 inches dbh. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire.

Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latitude and elevation, there can be from one to four generations per year. The generations are difficult to distinguish because the prolonged period of initial attack and re-emergence of parent females to establish additional broods causes considerable overlapping of the generations.

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pheromones released during a successful attack attract other western pine beetles. Attacking beetles may spill over onto nearby apparently healthy trees and overwhelm them by sheer numbers. Pitch tubes and red boring dust are indications of successful attacks.

Adults bore a sinuous gallery pattern in the cambium and the female lays eggs in niches along the sides. The larvae feed in the inner bark for a short distance and then turn into the outer bark to complete development.

Bluestain fungi introduced during successful attacks probably contribute to the rapid mortality associated with bark beetle attacks.

Woodpeckers, predaceous beetles and low winter temperatures cause natural control. Silvicultural activities that result in rapid, vigorous tree growth increases tree resistance and prevents mortality. Individual high value trees undergoing a temporary reversible stress, such as drought, can be protected for up to a year by applying insecticides to the bole.

Red Turpentine Beetle

The red turpentine beetle, Dendroctonus valens, occurs throughout California and can breed in all species of pines. It normally attacks injured, weakened or dying trees and freshly cut stumps. The adults are attracted by fresh pine resin. They often attack wounded trees in campgrounds or following logging, trees scorched by wildfire or prescribed burns, lightning-struck trees and root-diseased trees exhibiting resinosis.

Attacks usually occur at the soil line or root crown and are characterized by a large reddish pitch tube at the point of entry. On severely stressed trees or during periods of drought, attacks may occur underground on the main roots up to 15 feet from the bole and also on the bole to a height of 10 feet. If an attack is successful, the adults excavate an irregular gallery in the cambium and the female lays eggs along the sides. The larvae feed in a mass and destroy an area of cambium ranging from 0.1 to 1.0 square feet. Attacks do not always kill trees but may predispose them to attack by other bark beetles. Repeated or extensive attacks by the red turpentine beetle can kill pines.

Attacks occur throughout warm weather and peak at mid-summer. The number of generations varies from two years for a single generation at the coldest portions of its range to two or three per year in the warmest.

Attacks can be minimized or prevented by avoiding soil compaction and injury to standing trees during logging or construction and also by insecticide application to high value trees.

Fir Engraver

The fir engraver (Scolytus ventralis) attacks both white and red fir in California. Trees ranging in size from large saplings to overmature sawtimber are susceptible. Attacks can cause patch-killing of cambium along the bole, top-kill, or tree death. Top-kill or death occur most often in firs that have been weakened by root disease, dwarf mistletoe, overstocking, soil compaction, sunscald, logging injury, or drought. The fir engraver also breeds in slash and windthrown trees.

The fir engraver usually completes its life cycle in one year, sometimes two. Adults fly and bore into trees or green fir slash from June to September; larvae, pupae, and adults over-winter under the bark. Pitch tubes are not formed as they are with pine bark beetles; the usual evidence of attack is boring dust in bark crevices along the trunk and pitch streamers on the mid and upper bole. Trees colonized early in the summer may begin to fade by early fall, but those colonized later in the year usually do not fade until the following spring or summer, often after the beetles have emerged.

Sequoia Pitch Moth

The sequoia pitch moth, Vespamima sequoiae, is a clearwinged moth in the Family Sesiidae (Lepidoptera). The adults are black and yellow, resemble a wasp, and are characterised by having narrow wings that tend to be transparent and unscaled (hence the name "clearwinged" moth). The sequoia pitch moth ranges from British Columbia to Idaho, Montana and California. It attacks several species of Pinus, including ponderosa, lodgepole, Monterey and sugar pine. It also occasionally attacks Douglas-fir but has apparently not feed on Sequoia. It has a two year life cycle. The larvae bore into and feed in the cambium region causing copius pitch masses to form on the bole. Attacks are frequently associated with injuries and at the junctions of the limbs and the bole. It is generally considered an ornamental pest but repeated attacks over several years can cause significant damage, particularly to young, small-diameter, trees. The sequoia pitch moth has been recorded attacking young ponderosa pines prunned to create/maintain fuel breaks. The resulting pitch masses are considered to be somewhat of a fire hazard if prescribed burning is used to maintain the break.

Western Dwarf Mistletoe

Dwarf mistletoes (Arceuthobium spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts. Western dwarf

mistletoe (A. campylopodum) infects principally ponderosa, Jeffrey, and knobcone pines, and occasionally Coulter and lodgepole pines.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occasionally vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of Digger pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached, and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

White Pine Blister Rust

Blister rust (Cronartium ribicola) is caused by an obligate parasite that attacks sugar and western white pines and several species of Ribes. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on Ribes. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to Ribes where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves re-infect other Ribes throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on Ribes leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a

canker. After 2 or 3 years, spores are produced on the cankers and are spread to Ribes to continue the cycle. Although blister rust may spread hundreds of miles from pines to Ribes, its spread from Ribes back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers (these are called **lethal** cankers). Bole cankers result in girdling and death of the tree above the canker. Cankers whose closest margins are more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result (these are called **non-lethal** cankers).

Environmental conditions are critical for successful infection and limit the disease in most years. Moisture and low temperatures favor infection of both hosts, and must coincide with spore dispersal for infection to occur. In California, these conditions occur only infrequently, usually in cool moist sites such as stream bottoms or around meadows. In so called "wave years" when favorable conditions occur, high levels of infection can result. Wave years in California have occurred at approximately ten-year intervals in the past. As one moves from sites most favorable for rust to less favorable sites, the frequency of wave years decreases.

Annosus Root Disease In True Fir

Heterobasidion annosum (formerly Fomes annosus) is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone and a few brush species (Arctostaphylos spp. and Artemisia tridentata) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all the National Forests in California, with incidence particularly high on true fir in northern California campgrounds. Incidence is somewhat higher in older, larger fir stands and in stands with high basal areas (over about 330 square feet/acre).

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers begin by aerial spread of spores produced by the conks and subsequent colonization of freshly cut stump surfaces or wounds on living trees. The fungus then spreads through root contacts into the root systems of adjacent live true fir. Local spread of the fungus from a stump typically results in the formation of a disease center, with dead trees in the center and fading trees on the margin. These centers usually continue to enlarge until they reach natural barriers such as stand openings or non-susceptible plants.

In pines, H. annosum grows through root cambial tissue to the root crown where it girdles and kills the trees. In less resinous species such as true firs, the fungus sometimes kills trees, but more frequently it is confined to the heartwood and inner sapwood of the larger roots where it causes a chronic butt and root decay and growth loss. Thus, while infection in true fir usually does not kill the host, it does affect its

growth and thriftiness. Losses in true fir from H. annosum are mainly the result of windthrow because of root decay, and reduced root systems that predispose trees to attack and eventual death by the fir engraver beetle. Field observations suggest that vigorous young firs are usually able to regenerate root tissues faster than they are lost to the root disease. But when true firs slow in growth because of stand and/or site conditions, root development decreases to where there is a net loss in roots and the trees slowly decline due to the gradual loss of their root systems. This decline may take 10 to 20 years before tree death occurs.

There are two pathogenic strains of the fungus that differ in their ability to infect various conifers in California. The "P" or pine type infects and kills all pines (although susceptibility of pine species vary), in addition to incense-cedar and western juniper. The "S" or fir type infects true fir and giant sequoia. Ah this time it is not certain which strain attacks Douglas-fir. Knowing which type is active in a stand will allow favoring alternate conifer species since the fungus strains do not cross infect between the two groups listed above.

True Mistletoe

True, or leafy, mistletoes are parasitic plants in the genus Phoradendron with mature shoots more than six inches long. The size of their shoots help to distinguish them from dwarf mistletoes. The foliage of true mistletoes may be leafy or scaly, and their fruit is a round berry. They are mainly parasites of hardwoods but also infect several species of conifers in California, and obtain water and minerals from their host.

This pest is spread mainly by birds, including robins, bluebirds, thrushes, and cedar waxwings. Birds feed on the berries, digest their pulp, and excrete the living seed, often depositing them onto susceptible trees. A viscous coating and hair-like threads on the outer surface of the seeds attach them firmly to twigs and branches, where they germinate and infect host tissues.

Young or small trees are seldom infected by true mistletoe. In nearly all cases, initial infection occurs on the branches of larger or older trees because birds prefer to perch in their tops. Severe buildup of mistletoe often occurs in an already-infected tree because birds are attracted to and may spend prolonged periods feeding on the mistletoe berries.

True mistletoes are often considered to be curiosities, but they can be serious pests where individual trees are of high value, as in yards, parks, and campgrounds. Heavily infected trees are weakened, reduced in growth rate, and sometimes killed. Weakened trees are predisposed to attacks by insects and often die during drought or other periods of stress. Branches and tree tops heavily-laden with true mistletoe often break during wind storms, increasing the hazard to people and property in campgrounds and other developed sites.